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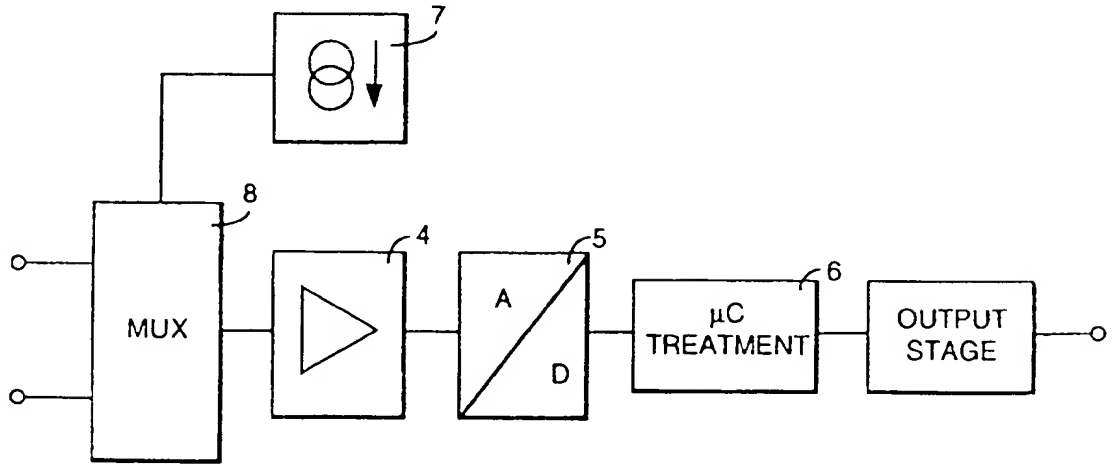
(54) Title: TRANSMITTER SENSOR




(57) Abstract

A temperature transmitter in an oil refinery has a thermowell located in a pipe within the petroleum processing section; the thermowell has two thermocouples (1 and 2) for sensing and measuring the petroleum flow. Thermocouple (1) is regularly checked for malfunction and if its resistance exceeds a threshold voltage then it is replaced by switching in thermocouple (2) which was not previously in use.

# TRANSMITTER SENSOR

The present invention relates to a transmitter sensor.

A transmitter sensor for use in manufacturing processes has a sensing probe in the medium to be measured and linked to the main unit of the transmitter for initial processing and/or analysis of the sensed data. The unit and probe are often placed a number of meters apart due to the hazardous or unpleasant nature of the medium or inaccessibility of the location in which the sensing has to be done.

The sensing probe has a thermowell to contain and protect a thermocouple to measure characteristics of the medium. Frequently a thermocouple breaks, requiring the manufacturing operation to be halted while the thermocouple is replaced. In one form of thermowell, in addition to the thermocouple connected in circuit and being used, the thermowell contains one or more additional unconnected thermocouples so that, when the thermocouple in use breaks, the operator can wire another thermocouple to the transmitter.

In another type of thermowell, there are provided a number of thermocouples grouped to give a composite reading so that if one thermocouple malfunctions, an adjustment in the reading is made to compensate for the loss.

The present invention provides a transmitter sensor comprising a transmitter sensor head remote from a station for the processing of

information derived by the sensing head, the sensor head characterised by means to switch operation from one thermocouple sensor means, for the sensing of a parameter for measurement in the locality of the sensor head, to another such thermocouple sensor means which had not been in use, upon malfunction of the said one thermocouple sensor means.

In use, and hence when fitted with thermocouple sensor means, the present invention provides a transmitter sensor comprising a sensor head remote from a station for the processing of information derived by the sensing head, the sensor head characterised by: at least two thermocouple sensor means for the sensing of a parameter for measurement in the locality of the sensor head; and means to switch operation from one thermocouple sensor means upon malfunction to another which had not been in use.

In this way, there is provided a back-up thermcouple sensor means which is only put into operation once the thermcouple sensor means in use malfunctions.

Thus, the invention enables the continued effective operation of the transmitter sensor even in the event of a thermcouple sensor means malfunction, while providing a low-cost reliable arrangement.

The present invention may also provide any one or more of the following features:

means to monitor the thermocouple sensor means for failure or deterioration;

the means to monitor comprises means to test the state of the thermocouple sensor means which is not in use;

the means to monitor is operable to test the thermocouple sensor means which is not in use less frequently than the thermocouple sensor means which is in use;

the means to monitor comprises means to determine whether a characteristic of the thermocouple sensor means has exceeded a threshold value;

the means to monitor comprises means to measure the resistance of thermocouple sensor means, and/or means to measure the change in resistance of thermocouple sensor means with respect to time;

the means to monitor includes means to apply a current signal to thermocouple sensor means.

The present invention also provides a method of operating a transmitter sensor comprising a sensor head remote from a station for the processing of information derived by the sensing head, the method characterised by switching operation from one thermocouple sensor means for the sensing of a parameter for measurement in the locality of the sensor head to another thermocouple sensor means which had not been in use, upon malfunction of the said one thermocouple sensor means.

Accordingly, the present invention can provide a simple and low cost arrangement which eliminates the need for stopping the manufacturing process when failure of a thermocouple occurs. Replacement of the broken thermocouple can be delayed until a convenient intermission in the manufacturing process arises.

The present invention is applicable to a wide variety of types of apparatus incorporating thermocouples, including in particular to all types of transmitter sensors including flow transmitter sensors, temperature

transmitter sensors and pressure transmitter sensors, to controllers and to recorders.

In order that the invention may more readily be understood, a description is now given, by way of example only, reference being made to the accompanying drawings in which:-

Figure 1 is a schematic diagram of a transmitter sensor embodying the present invention;

Figure 2 is a block diagram of operation of the sensor of Figure 1; and

Figure 3 is a flow chart showing operation of the sensor of Figure 1.

A temperature transmitter sensor for use in an oil refinery has a thermowell located in a pipe within the petroleum processing section such that the thermowell is in the stream of petroleum as it passes along the pipe. The thermowell is linked to a main unit of the transmitter situated on the exterior of the pipe. The thermowell contains two high temperature thermocouples 1 and 2 each of which has a platinum/6% rhodium alloy wire and a platinum/30% rhodium alloy wire.

The main unit has an electronic controller 3 whose port A is linked to one side of both thermocouples while port B is linked to the other side of thermocouple 1 and port C is linked to the other side of thermocouple 2. Ports D and E are used as outputs.

In normal operation, ports A and B (see Figure 1) are enabled so that thermocouple 1 is used for sensing and measurement of the petroleum flow by measurement of the e.m.f. from the thermocouple with processing including amplification with configurable gain at amplifier 4, digital conversion at A/D converter 5 and treatment by the microprocessor 6. Every

0.5 seconds, constant current generator 7 in microprocessor unit 3 injects via multiplexer 8 a current signal, $i_1$ of 170 micro Amperes and duration 80 milli seconds out through port A and into thermocouple 1. The resultant voltage drop $V_1$ across ports A and B, which is dependent on the resistance $R_1$ of thermocouple 1, is measured and if it exceeds a threshold voltage of 20 millivolts (the actual size of voltage can vary according to application), microprocessor 6 disables port B and enables port C while outputting a non-critical alarm to the operator of the oil refinery. Current generator 7 injects a current signal, $i_1$, in similar manner as for thermocouple 1 through port A and the voltage drop $V_2$ between ports A and C is measured; provided that $V_2$ is less than the same threshold voltage, the microprocessor unit 6 utilizes the e.m.f. of thermocouple 2 in all subsequent measurements of the parameter of the petroleum flow. Failed thermocouple 1 is replaced by an engineer at the next convenient opportunity for interrupting the processing in the relevant part of the oil refinery.

In a variation, in addition to or in place of the monitoring of resistance, controller 3 uses stored information about measured resistance and calculated change of resistance in order to monitor the change of resistance with time, such that once a threshold limit is exceeded, the switching of use from one thermocouple to another is done. When both monitoring methods are utilised, the switching between thermocouples can be done when one or both (or any specified sequence of) threshold(s) is or are exceeded. Thus for example, in one implementation, a given rate of change of resistance with time might not be considered of concern when the resistance is at one, comparatively low value, but the same rate of change of resistance might be considered of great concern if it occurs when the resistance is at a higher value, closer to the threshold resistance.

If the voltage $V_2$ exceeds an appropriate threshold, the controller unit outputs a critical alarm to the operator of the oil refinery so that a decision can be made as to whether the petroleum operation is to be stopped for the failed thermocouples to be replaced.

The controller can operate such that, when the failed thermocouple 1 has not yet been replaced so the thermocouple 2 is operating with no back-up, then the appropriate thresholds (e.g. for producing a warning signal) are different, typically lower, than when a thermocouple is operating with a back-up.

The normal voltage drop across the thermocouples 1 or 2 for the injected current would be for example 2 millivolts representing a thermocouple resistance of 10 Ohms, and the threshold value of 20 millivolts (i.e. thermocouple resistance of 118 Ohms) represents the point at which performance of such a thermocouple has significantly deteriorated and a warning signal is to be generated, whereas the further threshold value of 35 millivolts, (i.e. 200 Ohms) represents the point at which there is danger of the thermocouple imminently failing. Either threshold can be used as that which causes change of the thermocouples. A resistance change of 10 Ohms/minute is an indication of a problem with the thermocouple, the values when monitoring of resistance change being very application specific. The controller unit is able to measure resistances in the range 0 to 2000 Ohms, and resistance changes in the range 50 Ohms/second to 1 Ohm/day.

Additionally to the substitution of thermocouple 1 by thermocouple 2, controller 3 can activate a warning signal indicating failure or deterioration, and/or cause other appropriate action. The controller can estimate failure of a thermocouple based on the measurement of resistance or change of

resistance with respect to time, and display or otherwise output the results together with the warning signal, or produce a suitably modified warning. The controller 3 can also determine the relationship between the estimated failure time and the next service or maintenance due, and give an appropriate signal.

In one modification, the controller 3 provides temperature compensation of the resistance, and/or change of resistance, measurements. In normal use of a thermocouple such as to obtain a temperature reading at the thermocouple, the e.m.f. voltage of the hot junction is measured and compensated with the e.m.f. voltage of the cold junction. Thus, when determining the resistance and/or change of resistance value, the measured voltage after injection of the current is compensated with the previously measured thermocouple e.m.f. to obtain the corrected resistance of the hot junction. Assuming that the resistance of the lead wires and the connection resistance is zero, then

$$R_{hot\text{-}junction} = (V_{measured} - V_{e.m.f.}) / I_{constant.}$$

In applications utilizing long thermocouple wires or compensation cables, the lead wire resistance can be significant in relation to the hot junction resistance (albeit constant in time), such that:-

$$R_{lead\text{-}wire + connection} = (V_{measured} - V_{e.m.f.}) / I_{constant}$$

If controller 3 notes and stores the resistance of the lead wire and of the connection at $t = 0$ (referred to as $R_{to}$), then the corrected resistance is:-

$$R_{hot\text{-}junction} = (V_{measured} - V_{e.m.f.}) / I_{constant} - R_{to}$$

The microprocessor 6 may effect intermittent checks of thermocouple 2 even when thermocouple 1 is in circuit and being used for measurement of

the petroleum, such checks being typically less frequent than those of thermocouple 1.

The thermowell may have a third or more thermocouple(s) to be switched into operation in case thermocouple 2 fails before thermocouple 1 is replaced; the status of all thermocouples not in use at any time may be checked, and the frequency of such checks may be the same for all thermcouples not in use, or they may vary in relation to the condition of the thermocouple (for example the frequency can increase as the checks as the values approach a threshold) and/or the sequence in which they will take over operation.

The invention ensures that, at minimal complexity and cost, the processing operation of the oil refinery is not interrupted by failure of a thermocouple.

## CLAIMS

1. A transmitter sensor comprising a transmitter sensor head remote from a station for the processing of information derived by the sensing head, the sensor head characterised by means to switch operation from one thermocouple sensor means, for the sensing of a parameter for measurement in the locality of the sensor head, to another such thermocouple sensor means which had not been in use, upon malfunction of the said one thermocouple sensor means.

2. A transmitter sensor comprising a sensor head remote from a station for the processing of information derived by the sensing head, the sensor head characterised by: at least two thermocouple sensor means for the sensing of a parameter for measurement in the locality of the sensor head; and means to switch operation from one thermocouple sensor means upon malfunction to another which had not been in use.

3. A sensor according to Claim 1 or 2 characterised by means to monitor the thermocouple sensor means for failure or deterioration.

4. A sensor according to Claim 3 characterised in that the means to monitor comprises means to test the state of the thermocouple sensor means which is not in use.

5. A sensor according to Claim 4 characterised in that the means to monitor is operable to test the thermocouple sensor means which is not in use less frequently than the thermocouple sensor means which is in use.

6. A sensor according to any of Claims 3 to 5 characterised in that the means to monitor comprises means to determine whether one or more characteristics of the thermocouple sensor means has exceeded a threshold value.

7. A sensor according to any of Claims 3 to 6 characterised in that the means to monitor comprises means to measure the resistance of thermocouple sensor means and/or means to measure the change in resistance of thermocouple sensor means with respect to time.

8. A sensor according to any of Claims 3 to 7 characterised in that the means to monitor includes means to apply a current signal to thermocouple sensor means.

9. A sensor according to any preceding Claim, characterised in that the switch means comprises a solid-state device with means to disable a port to one thermocouple sensor means and means to enable a port to another thermocouple sensor means upon malfunction of the one thermocouple sensor means.

10. A sensor according to any preceding Claim characterised by thermocouple sensor means for the sensing of a parameter for measurement in the locality of the sensor, the sensor comprising means to predict failure or deterioration of the thermocouple sensor means.

11. A sensor according to Claim 10 characterised by means to estimate failure of thermocouple sensor means comprising means to determine whether the rate of change of one or more characteristics of the thermocouple sensor means has exceeded a threshold value.

12. A sensor according to Claims 10 or 11 characterised by means to estimate failure of thermocouple sensor means based on measured values of change of resistance with respect to time of thermocouple sensor means.

13. A sensor according to any of Claims 10 to 12 characterised in that the estimation means comprises means to measure the change in resistance of thermocouple sensor means with respect to time.

14. A sensor according to any of Claims 10 to 13 characterised in that the estimations means comprises means to note a combination and/or sequence of values of resistance, and of change in resistance with respect to time, of thermocouple sensor means.

15. A sensor according to any of Claims 10 to 14 characterised in that the estimation means includes means to apply a current signal to thermocouple sensor means.

16. A sensor according to any of Claims 10 to 15 characterised by means to generate a warning signal in response to an output of the estimation means.

17. A method of operating a transmitter sensor comprising a sensor head remote from a station for the processing of information derived by the sensing head, the method characterised by switching operation from one thermocouple sensor means for the sensing of a parameter for measurement in the locality of the sensor head to another thermocouple sensor means which had not been in use, upon malfunction of the said one thermocouple sensor means.

18. A method of operating a transmitter sensor comprising a sensor head remote from a station for the processing of information derived by the sensing head, the sensor head having two thermocouple sensor means for the sensing of a parameter for measurement in the locality of the sensor head; the method characterised by switching operation from one thermocouple sensor means upon malfunction to the other which had not been in use.

19. A method according to Claim 17 or 18 characterised by monitoring the thermocouple sensor means for failure or deterioration.

20. A method according to Claim 19 characterised in that the monitoring step comprises testing the state of the thermocouple sensor means which is not in use.

21. A method according to Claim 20 characterised in that the monitoring step is operable to test the thermocouple sensor means which is not in use less frequently than the thermocouple sensor means which is in use.

22. A method according to any of Claims 19 to 21 characterised in that the monitoring step comprises determining whether one or more characteristics of the thermocouple sensor means has exceeded a threshold value.

23. A method according to any of Claims 17 to 23 characterised in that the monitoring step comprises measuring the resistance of the thermocouple sensor means, and/or measuring the change in resistance of thermocouple sensor means with respect to time.

24. A method according to any of Claims 17 to 23 characterised in that the monitoring step includes applying a current signal to the thermocouple sensor means.

25. A method according to any of Claims 17 to 24 characterised in that the switching step comprises disabling a port of a solid-state device to one thermocouple sensor means and enabling a port to another thermocouple sensor means upon malfunction of the one thermocouple sensor means.

26. A method according to any of Claims 17 to 25 characterised by predicting failure or deterioration of the thermocouple sensor means.

27. A method according to Claim 26 characterised by estimating failure of thermocouple sensor means comprising determining whether the rate of change of one or more characteristics of the thermocouple sensor means has exceeded a threshold value.

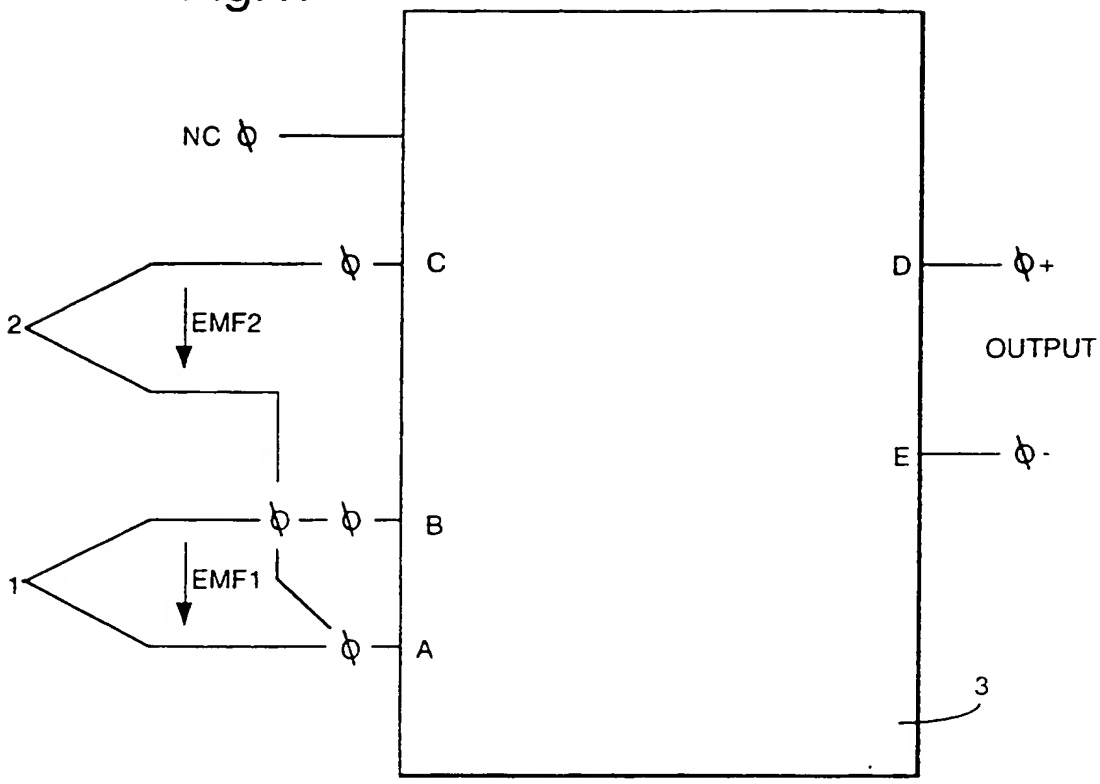
28. A method according to Claim 26 characterised by estimating failure of thermocouple sensor means based on measured values of change of resistance with respect to time of thermocouple sensor means.

29. A method according to any of the Claims 25 to 28 characterised in that the monitoring step and/or the estimating step includes applying a current signal to the thermocouple sensor means.

30. A method according to any of Claims 25 to 28 characterised in that the monitoring step and/or the estimating step comprises means to note

a combination and/or sequence of values of resistance, and of change in resistance with respect to time, of thermocouple sensor means.

Fig.1.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B
1
EMF1
A
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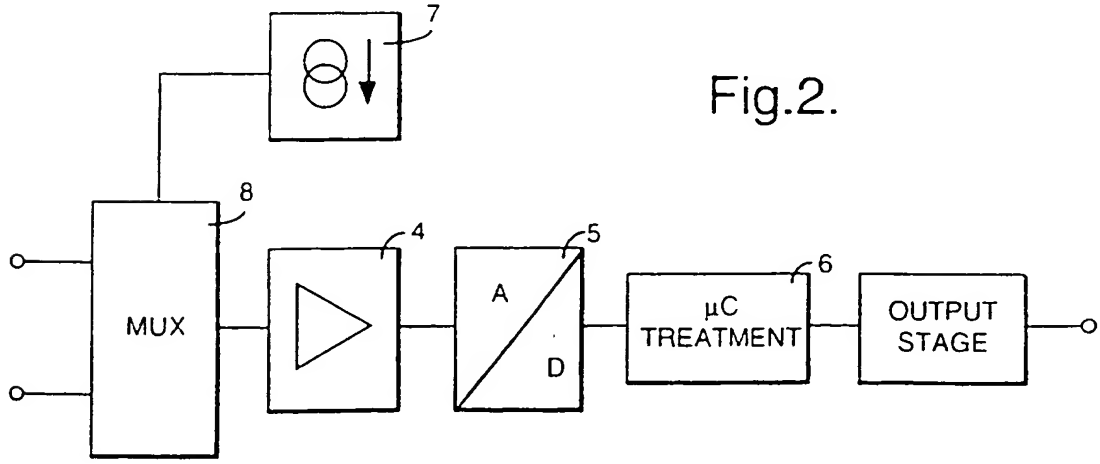
7
8
4
5
6
MUX
A
D
µC
TREATMENT
OUTPUT
STAGE

Fig.2.

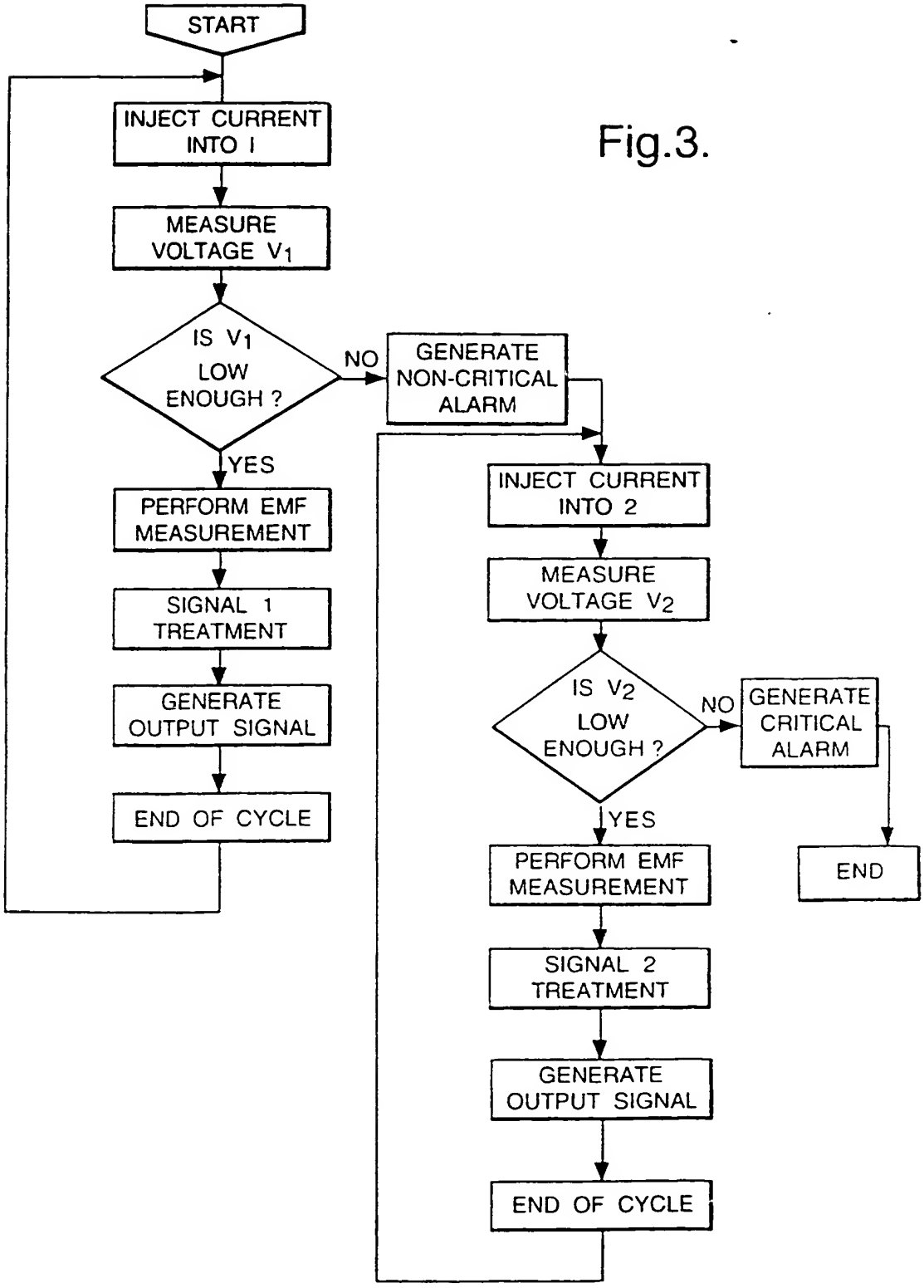
START
INJECT CURRENT INTO 1
MEASURE VOLTAGE $V_1$
IS $V_1$ LOW ENOUGH ?
NO
GENERATE NON-CRITICAL ALARM
YES
PERFORM EMF MEASUREMENT
SIGNAL 1 TREATMENT
GENERATE OUTPUT SIGNAL
END OF CYCLE
INJECT CURRENT INTO 2
MEASURE VOLTAGE $V_2$
IS $V_2$ LOW ENOUGH ?
NO
GENERATE CRITICAL ALARM
YES
PERFORM EMF MEASUREMENT
SIGNAL 2 TREATMENT
GENERATE OUTPUT SIGNAL
END OF CYCLE
END

Fig.3.

# INTERNATIONAL SEARCH REPORT

Inter vnal Application No
PCT/IB 95/00890

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01K7/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | FR,A,2 673 288 (NIPPON ELECTRIC CO) 28 August 1992<br>see page 4, line 13 - page 5, line 7 | 1-4,9,<br>17-20 |
| X | US,A,2 457 791 (R.F. WILD) 28 December 1948<br>see column 15, line 3 - column 17, line 12; figures 4-7 | 1,17 |
| A | DE,A,30 06 669 (BBC BROWN BOVERI & CIE) 27 August 1981<br>see page 4, line 12 - page 7 | 3,6,12,<br>19,22,<br>27,28,30 |

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[X] Further documents are listed in the continuation of box C.

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International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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|---|---|---|
| A | FR,A,2 302 514 (THE SOLARTRON ELECTRON GROUP LTD) 24 September 1976<br>see page 5, line 1 - page 7, line 26 | 3,6-8, 12-16, 19, 22-24, 27-29 |
| A | US,A,4 841 286 (KUMMER KARL T) 20 June 1989<br>see abstract; figures | 1 |

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

information on patent family members

Inter nal Application No
PCT/IB 95/00890

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| FR-A-2673288 | 28-08-92 | JP-A- 4271229 | 28-09-92 |
| | | US-A- 5255149 | 19-10-93 |
| US-A-2457791 | 28-12-48 | NONE | |
| DE-A-3006669 | 27-08-81 | NONE | |
| FR-A-2302514 | 24-09-76 | GB-A- 1534280 | 29-11-78 |
| | | DE-A- 2603797 | 09-09-76 |
| US-A-4841286 | 20-06-89 | NONE | |

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